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Assessment of car-following models by driver type and under different traffic, weather conditions using data from an instrumented vehicle

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ABSTRACT

Car-following models are important components of simulation tools, since they describe the behavior of the following vehicle as a function of the lead vehicle trajectory. Several models have been developed and evaluated using field data. However, the literature has been inconclusive regarding the applicability of various car-following models under different operational conditions such as congested vs. non-congested. There has been very limited research regarding the relationship between car-following calibration parameters and different driver types. The objective of this study was to assess four car-following models using field data under different traffic (congested vs. uncongested) and weather conditions (rain vs. clear sky) and for various driver types (aggressive, average, and conservative). The assessed models were the Gipps (component of the AIMSUN software), Pitt (component of the CORSIM software), MITSIM (utilized in MITSIMLab program), and the Modified Pitt model. The data used in the analysis were collected with the help of an instrumented vehicle. The field trajectories were compared to the trajectories obtained by each of the four models evaluated. Results showed that the variable predicted best by the models was the speed of the following vehicle, which is consistent with previous findings. The calibration analysis also showed that the best variable to be used for calibration is spacing. Calibrating by spacing minimizes the errors that can be accumulated and can distort the final trajectory. Three calibration analyses were completed: first using all data available, second by traffic condition, and third by driver type. The best results were obtained when the parameters were calibrated by driver type using the MITSIM model. The study concludes with recommended calibration parameters, and application guidelines related to the car-following models examined.

1. Introduction

Microsimulation programs are developed and implemented world-wide and their characteristics have been based on different algorithms of microscopic driver behavior. These algorithms model lane changing, gap acceptance and car-following behavior. Car-following models describe the behavior of the following vehicle as a function of the lead vehicle trajectory. Knowing the lead vehicle trajectory and using the car-following models one can estimate or predict the following vehicle

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trajectory in response to the lead vehicle's actions. Existing car-following models typically consider the speed of the lead and following vehicles, the acceleration of the lead vehicle, the reaction time of the following vehicle, as well as the spacing and relative speed.

In an effort to replicate driver behavior variability that is met in real-life conditions, various microsimulation models typically include different driver types, and assign probabilities which are associated with the degree of aggressiveness of each driver type (for instance, CORSIM has ten different driver types). Therefore, in an effort to provide realistic representation of traffic conditions through simulation, it is very important to understand how actual driver behavior variability relates to the microscopic driver behavior algorithms used in microsimulation.

The purpose of this paper is to assess selected car-following models and their performance against field data under different conditions (congested, uncongested and rain with/without congestion), and for different driver types (conservative, average and aggressive). Such a comparison would result in a better understanding of existing car-following models, and could advance our knowledge in their application within microsimulation.

More specifically the objectives of this study are to:

- Calculate the projected trajectories for selected car-following models under different traffic conditions and compare the model-estimated trajectories with those obtained in the field.
- Compare the following:
  - Trajectories obtained by the selected models.
  - Trajectories obtained under different conditions (congested vs. uncongested, and rain vs. no rain).
  - Trajectories obtained among different drivers.
- Provide recommendations regarding improvements to existing car-following models and their application.

The next section discusses the car-following models selected and previous studies comparing car-following models to field data. The third section describes the field data used while the fourth section discusses the variable estimated by each car-following model, and impacts on calibration. The fifth section presents the data analysis and calibration while the last section provides conclusions and recommendations.

2. Literature review

The first part of the literature review briefly summarizes the different car-following algorithms and research findings that study the effect of driver variability and traffic flow regimes in car-following. The next part of the literature review discusses past research on calibrating well known car-following models used within microsimulation models. The final part of the literature review briefly presents the car-following models presented in this research.

2.1. Driver behavior variability and traffic congestion in car-following

Car-following models have been studied extensively for more than half a century. In recent years, the interest of car-following models has increased dramatically, due to the extensive developments in microsimulation, and progress in advanced vehicle control and safety systems (AVCSS). A study by Brackstone and McDonald [2] classified car-following models into five groups as follows: Gazis–Herman–Rothery (GHR) model, collision-avoidance model (CA), linear model, psychophysical or action-point model (AP), and fuzzy logic-based model.

Several researchers have studied differences in car-following due to driver behavior variability. A large number of these studies have implemented instrumented vehicles to provide further understanding of driver behavior. Brackstone et al. [3] studied car-following behavior with the use of an instrumented vehicle on British freeways. The car-following data include observations of drivers following the instrumented vehicle. The authors concluded that drivers follow their leaders in shorter headways than previously thought. Brackstone et al. [4] extended their instrumented vehicle experiments to study factors that affect the decision making process of car-following. According to their findings, headways would vary based on the type of the lead vehicle (subjects followed closer to trucks than passenger cars), and for the same driver, these variations would change from day to day.

Kim et al. [19] analyzed car-following behavior using an instrumented test vehicle equipped with four sets of instrumentation, including an infrared sensor, GPS-inertial distance measuring instrument (DMI), vehicle computer and a digital video camera. These data were collected during peak and non-peak hour periods near Washington, DC, for 301 car-following time series and an average duration of 99 s. The researchers observed and analyzed the car-following behavior of subjects that do not know they are part of the experiment. They concluded that there is an oscillatory process in car-following behavior formed by the vehicles desiring to keep their following distance. They also concluded that each individual driver has his or her driving rules rather than a deterministic driving law, and their distance can vary over time and space during different driving conditions. The reactions of the following vehicle caused by the same maneuver in car-following situations repeat themselves over time and space.

Ranjitkar et al. [31] performed analysis of the acceleration time series plots for four drivers, to investigate the stability criterion for the following vehicles (driver sensitivity times the reaction time). Based on the results, the majority of drivers